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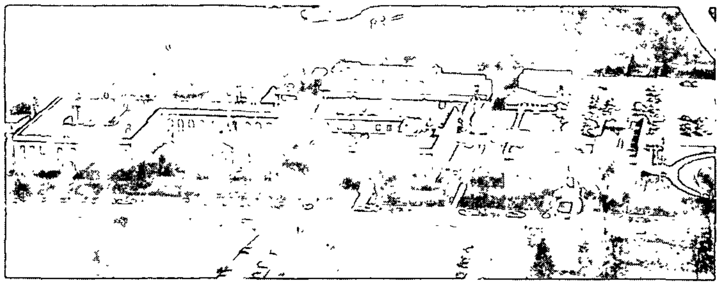

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IMPROVED BONDING IN GROUNDWOOD FURNISHES

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IMPROVED BONDING STRENGTH OF GROUNDWOOD FURNISHES

Joseph J. Becher, Gerald R. Hoffman, and John W. Swanson

INTRODUCTION

Groundwood pulps have many desirable properties such as low cost, high opacity and good printing qualities. However, they are notoriously poor in bonding strength and, as a result, the groundwood content in most mixed furnishes is rather limited. There are several reasons for the lower strength of groundwood papers: (1) Groundwood is a mixture of coarse fiber bundles, individual lignified fibers, broken fibers, and fines. The large proportion of short fiber material makes it difficult to achieve high strength. (2) Groundwood contains essentially the same lignin and extractives content as the original wood. The fibrous material is therefore not responsive to mechanical beating and refining and does not produce the associated swelling and fibrillation necessary for good interfiber bonding. If the bonding ability of groundwood pulps could be improved, more groundwood could be substituted for expensive chemical pulps. The result should be a significant reduction in cost while maintaining product standards. A process is described for rapidly improving the strength properties of groundwood pulps by increasing the swelling and conformability of fibers and fiber elements.

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Improved Bonding in Groundwood Furnishes

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ABSTRACT

A process is described for producing rapid improvements in the strength properties of aspen stone groundwood and chemirefiner pulps. The process consists of passing a stream of pulp at 4-5% consistency through a continuous steam jet cooker for six seconds at elevated temperatures in the presence of alkali equivalent to roughly 0.3-0.4% in solution. The treated groundwood pulp at a yield of 95-98% was found to approach or exceed 100% bleached softwood kraft controls in tensile strength depending upon the conditions employed. The gains in strength were accompanied by increases in density and decreases in porosity and brightness. Tear strength and opacity were relatively unaffected. The brightness loss was offset by incorporating 1.2-1.3% of peroxide into the cooking liquor before steam jet treatment or by medium density bleaching with 0.8% peroxide after jet treatment. Scanning electron photomicrographs of the treated groundwood show a high degree of plasticization of fiber elements and some laterial rupture of fibers. The net result is a web of greatly increased density and strength. While the jet/alkali process was not found to be unique, it offers a means of upgrading aspen stone groundwood and refiner pulps for those operations lacking thermomechanical capabilities.

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BACKGROUND

Means to improve the properties of groundwood pulps have led to the refiner and chemirefiner pulping systems which can utilize wood wastes and hardwoods to produce a longer-fibered, stronger pulp thereby permitting a reduction in the proportion of more expensive chemical pulps in some papermaking furnishes. Within recent years, thermomechanical pulps produced by the pressurized defibering of chips at elevated temperatures have drawn considerable attention. Pulps of this type have been produced which are stronger than stone groundwood and conventional refiner groundwood leading to the possibility of producing paper from 100% mechanical pulp. In the meantime, efforts have been made to upgrade stone groundwood primarily through improvements in the grinding operation. Some years ago, Foote and Parsons (1) described a method for increasing the strength of aspen groundwood based on alkaline treatments. These investigators found that substantial increases in tensile and bursting strength could be obtained by treating the groundwood for several hours in solutions containing in excess of 3% of alkali based on fiber weight. The gains in strength were accompanied by losses in brightness, bulk, and yield. Yield values in the range of 90-94% were obtained under conditions of maximum strength. While the alkaline treatments described by these investigators showed considerable promise as a means of improving the strength of aspen groundwood, the process was time consuming and subject to variations in wood quality. The jet/alkali process described in the present work builds upon the results of these earlier workers. Basically, the process involves treating mechanical pulps continuously at elevated temperatures and pressures, in the presence of alkali and lignin reactive chemicals. The purpose of this type of treatment is to produce a rapid swelling of fibers and fiber elements in order to render the components more conformable and thereby increase molecular contact and promote bonding between fiber surfaces during the drying operation. By limiting the exposure time to very short intervals, losses due to solubility of components should be minimized and yields increased. Further, a rapid continuous process would lend itself to versatility in pulping operations.

EXPERIMENTAL

A steam injection process was considered a possible means of applying heat and pressure to fiber suspensions over short time intervals. Accordingly, a steam jet cooker was assembled which would accommodate up to 5% stone groundwood or 4% refiner groundwood in water suspension. A schematic diagram of the cooker is given in Fig. 1. The groundwood suspension treated with the desired amounts of reactants was fed continuously through the cooker at elevated temperatues and the treated product was collected at a cyclone separator where evaporative cooling lowered the temperature to 195-200°F. The collected pulp was cooled in an ice bath to room temperature within approximately 10 minutes to arrest residual reactions which were promoted at the higher temperature. The pulp was sampled at this point for residual alkali and other reactants. The major portion of the collected material was then neutralized with dilute hydrochloric acid to pH 5 and samples were taken for consistency, yield, and freeness. Residual alkali was determined by titrating the un-neutralized pulp to pH 2 with 0.1N HCl. Two inflection points were obtained in the pH *vs.* HCl volume curves. The first, near pH 8, was presumed due to free alkali. The second, near pH 3.0, was considered combined alkali.

Handhseets equivalent to 63 g/M^2 were formed at pH 5 initially from 80/20 blends of the neutralized groundwood and a moderately beaten market-grade softwood bleached kraft (345 ml CSF). Eventually, sets were also formed from 100% treated groundwood. For purposes of control, sets were formed from 100% kraft, from blends of untreated groundwood and kraft and from 100% untreated groundwood. The handsheets were tested for strength, structural, and optical properties according to standard TAPPI procedures.

RESULTS AND DISCUSSION

A series of exploratory experiments was performed to test the feasibility of the continuous steam jet concept as a means of improving the quality of groundwood pulps. For this purpose, samples of stone groundwood and chemirefiner pulp from aspen were processed through the jet cooker for six seconds at 230°F in combination with several levels of alkali. The results showed substantial improvements in strength properties at the 6-sec treatment level for 80/20 blends of groundwood and kraft. Tensile strength and stiffness either approached or exceeded the values for the 100% kraft controls at yield values of 94-98%. The strength improvements were accompanied by increases in density and reductions in air permeability and brightness. Actually, the changes in strength and brightness were quite comparable to those reported by Foote and Parsons (1) but the time required to achieve the strength improvements was reduced from a matter of hours to six seconds.

Having established the potential usefulness of the jet/alkali process, additional tests were carried out to confirm the effectiveness of the system and to establish the conditions for producing the best balance in sheet properties. For this purpose, a second supply of aspen stone groundwood was processed at 5% consistency for six seconds at temperatures ranging from 190 to 280°F and alkali levels ranging from 0-8% based on fiber. The conditions providing the most desirable balance in properties were repeated at a 13-second dwell time which represented the maximum commensurate with smooth operation of the jet cooker. The results confirmed the effectiveness of the jet/alkali process for aspen groundwood. In general, density, tensile strength, tensile energy absorption (TEA), stiffness, and folding endurance tended to increase with alkali concentration whereas porosity, brightness, and scattering coefficient declined. Tear factor and opacity showed little change. Actually, some strength properties tended to level off or decline beyond the 6% alkali addition level. For this and economic reasons, the 6% alkali treatment level was selected for continued work.

With respect to processing temperature, the 280° treatment provided marginally better tear and brightness whereas the 190° treatment afforded superior folding endurance. However, in general, the intermediate processing temperature tended to provide the best tensile strength properties at the higher alkali levels. Increasing the dwell time to 13 seconds had little effect on strength and structural properties whereas brightness was reduced several units. On the basis of this exploration of process variables, the 6-second jet treatment along with the 6% alkali addition level and the 230° processing temperature were selected as affording the best balance in strength and optical properties.

The groundwood suspension data showed that free and combined alkali were relatively unaffected by cooking temperature and dwell time. Combined alkali paralleled the trend in tensile properties to the extent that both increased rapidly as the alkali level increased to about 6%

and then tended to level off at higher alkali levels. Hence, combined alkali appears to be a controlling factor in the jet/alkali process. The plateau region for aspen stone groundwood is approximately 40 mg/g, a level which would be expected to vary with the particular groundwood pulp involved. The yield values ranged from 96-99% and this is somewhat higher than that reported by Foote and Parsons (1).

One of the most objectionable effects of the jet/alkali treatment is the reduction in brightness. Means to offset this effect were examined in two sets of experiments: 1) Incorporation of selected agents into the pulp prior to jet treatment and 2) medium density bleaching with peroxide following jet/alkali treatment.

Under the first approach, sodium sulfite, sodium borohydride, and hydrogen peroxide were added at levels ranging from 0.1 to 7.0% depending upon the agent involved. The pH of the borohydride treated pulp was reduced with SO_2 after jet treatment thereby generating sodium hydrosulfite.

Sodium sulfite and sodium borohydride produced modest increases in both strength and brightness but the brightness levels fell short of that provided by the untreated groundwood/kraft controls. Hydrogen peroxide tended to reduce strength somewhat possibly due to degradation of cellulosic components under the conditions employed. However, brightness was substantially increased and the pulp was effectively bleached at peroxide levels in excess of 1.2-1.3%.

In contrast to the brightness loss series, medium density bleaching with peroxide produced modest improvements in strength properties along with improved bleaching efficiency. Approximately

0.8% peroxide was required to offset the loss in brightness and a difference of only 2-3% remained at the 2% peroxide level between untreated and jet/alkali treated groundwood. Yield values ranged from 95-99%. These values coupled with those obtained in the jet/alkali process provided an overall yield of approximately 94% for the bleached groundwood.

Having established that substantial improvements in strength can be attained in blends of the jet/alkali groundwood and kraft and having shown that the brightness loss associated with the process can be offset with less than 1% of peroxide while further improving strength, attention was drawn to 100% "groundwood" papers as representing an attractive potential application of the jet/alkali process. Accordingly, selected handsheets from 100% aspen groundwood were tested for strength, structural, and optical properties. Quite surprisingly, the strength properties of the treated groundwood, as shown in Table I, approached, equalled, or even exceeded the 100% kraft controls in breaking length depending upon the specific treatments. Maximum strength was produced with 3% of sodium sulfite (Set 7) in which case the all-groundwood paper provided a breaking length which was 2-3 times that of the untreated groundwood. Air permeability was greatly reduced in line with the increases in density. As would be expected, those properties which depend upon fiber length such as stretch and tear were at a low level. One of the most noteworthy results was provided by the bleached all-groundwood paper (Set 12) which equalled the strength of the unbleached jet-cooked product (Set 6) at 19-20 points higher brightness and it exceeded the tensile strength of the 50/50 groundwood/kraft controls at equal brightness.

It would be expected on the basis of the increased strength and density resulting from jet/alkali treatments that freeness and drainage properties would be drastically reduced. Indeed, freeness was reduced (Table I) although possibly not to the extent expected. For example, the decline in freeness for the strongest pulp was from 150 to 105 ml CSF although, in general, a decline of 50 or 60 ml was more common. An attempt to apply Forgacs' classification test (2) to the jet/alkali pulps did not prove successful and, in the absence of filtration resistance data or paper machine runnability tests, definite conclusions conerning drainage cannot be made.

SEM micrographs of untreated and jet/alkali-treated fibers shown in Fig. 2-4 indicate that several mechanisms may be involved in the process. The major effect appears to be one of greatly increased swelling and plasticization of whole fibers and elements as indicated in Fig. 3. These components are capable of improved bonding through enhanced conformability and increased contact area. There is also some evidence (Fig. 4) to suggest that a small number of fibers are ruptured along their length. These fibers which are plasticized with alkali are then free to unfold and encompass unreacted fibers and elements. The net result is a web of greatly increased density and strength but reduced porosity. Hence, it appears that the mechanism of strength improvement in the jet/alkali process differs from that of refiner groundwood and thermomechanical treatment of wood chips where the long fiber fraction is increased and strength improved while maintaining bulk and porosity. In general, however, the tensile strength improvements obtained from the jet/alkali treatment of aspen stone groundwood were greater than those reported for the aqueous thermomechanical treatment of softwoods (3,4).

As previously mentioned, the jet/alkali process offers advantages over the earlier method of Foote and Parsons (1). It was considered possible, however, that similar results could be attained with existing equipment and processes which would also offer an advantage in speed. Accordingly, a series of experiments was carried out to test the uniqueness of the jet/alkali process for aspen by comparing these pulps with thermomechanical (TM) pulps prepared in water and in alkali suspension.

Jet/alkali treatment of aspen chemirefiner and TM pulps provided expected improvements in strength. However, TM pulping in alkali produced equivalent or greater improvements compared to the jet/alkali treatments depending upon the alkali concentration. Roughly comparable results were obtained at an equal alkali concentration in solution (0.3%). At a higher alkali concentration ($\cong$ 1.1%), the TM pulp produced a dense, nonporous paper resembling a translucent glassine. In that case, the tensile and folding strengths far exceeded those of the 100% softwood kraft controls but at a substantial loss in brightness and opacity. The exceptionally high tensile and folding endurance of this paper coupled with a yield of 82% would appear to be of interest although the highly alkaline condition represents an extreme in treatment. Hence, the jet/alkali process was not shown to be unique; however, in the absence of TM pulping capabilities, the process offers the advantages of simplicity, speed, and high yield to those mills producing stone groundwood and nonpressurized refiner groundwood from aspen. Estimates based solely on the costs of energy and chemical indicate that the jet/alkali process would add $22-32/ton to the cost of groundwood depending upon the brightness level desired. Presumably, the added cost would be more than off-set if the treated pulps can be utilized in more expensive paper grades.

Efforts to apply the jet/alkali process to softwood groundwood met with only moderate success. A market groundwood from spruce proved to be moderately responsive whereas a southern pine stone groundwood was considerably more resistant to the process. Jet treatment (6 sec, 230°F) of the northern softwood in alkali concentrations in excess of 0.1% produced increases in strength such that the 80/20 blend of treated groundwood/kraft slightly exceeded the 50/50 controls in tensile. In order to produce roughly comparable strength in southern pine, it was found necessary to increase the processing temperature to 275 or 300°F and the alkali concentration to 0.6% in solution. In line with the lack of responsiveness indicated in the strength properties, the combined alkali in the case of the softwood species leveled off at 16-20 mg/g compared to 40 mg/g for aspen.

The differences in responsiveness of the wood species probably result from a number of factors related to chemical composition and fiber morphology. Differences in lignin, in the thickness and uniformity of the cell well, and in the proportion of early and latewood in the pulp samples could affect the responsiveness to alkali in short time intervals. In particular, the thick-walled structure of southern pine summerwood would tend to inhibit rapid penetration and response to alkali.

ACKNOWLEDGMENTS

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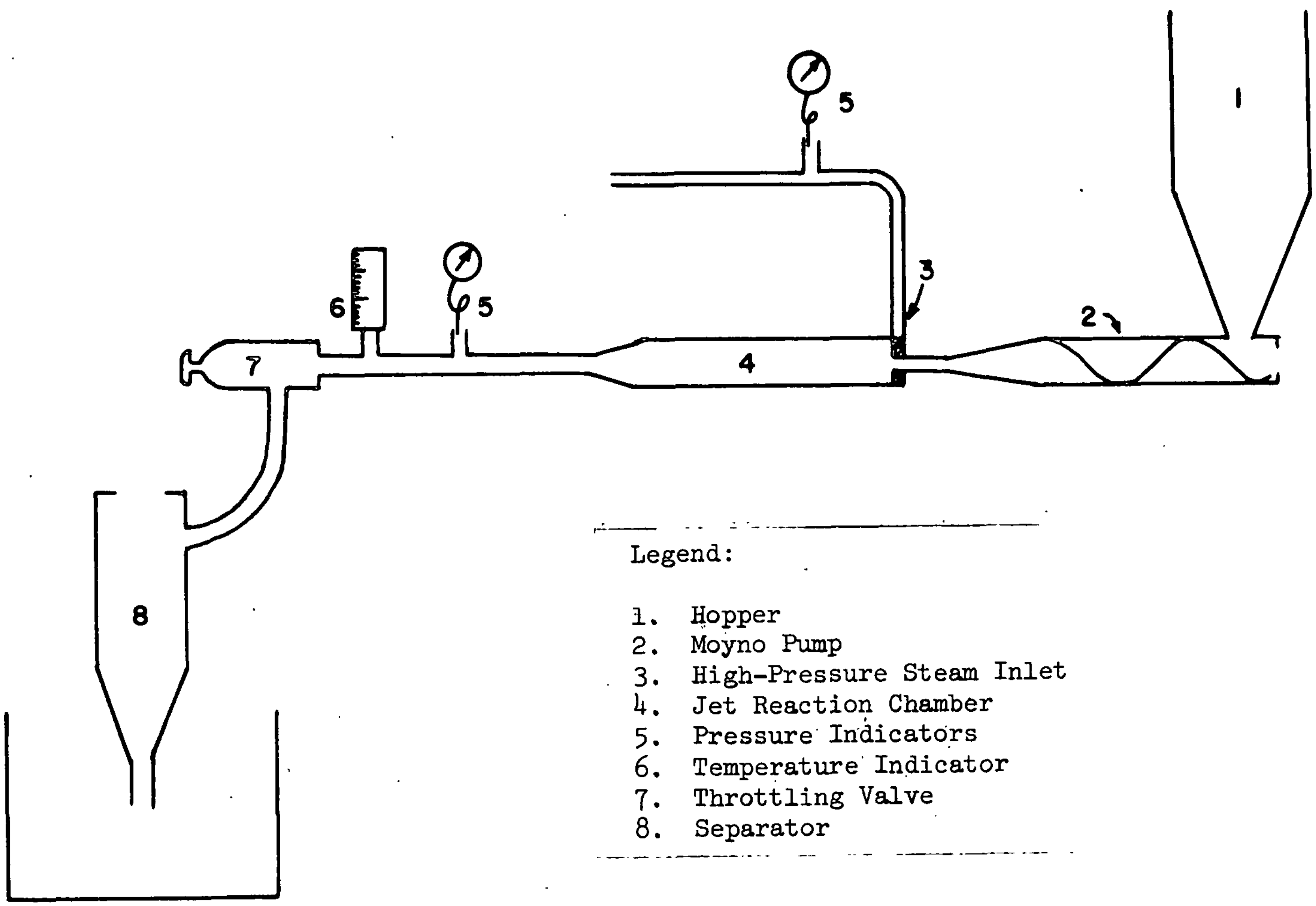
Table I. The Effect of the Jet Alkali Process on Groundwood Properties

Set No.	Description	Freeness of whole groundwood pulp, ml CF	Freeness of 48/100 fraction, ml CF	Fraction retained on 100 mesh, %	Basis wt., g/M^2	Thickness, µm	Density, g/cc	Breaking length, km	TEA, g-cm/sq cm	Stretch, %	Tensile stiffness, kg/cm	Tear factor, (single sheet)	Bendtsen air permeability, ml/min	Brightness, %	Opacity, %	Scattering coeff. sq cm/g
1	Control, 100% kraft	--	--	--	61.4	114	0.537	5.32	97.6	4.1	327	124.1	255	86.4	71.5	304
2	Control, 50/50 untreated groundwood/kraft	--	--	--	61.9	145	0.426	3.65	46.4	2.8	258	78.2	399	69.4	86.6	522
3	Control, 80/20 untreated groundwood/kraft	--	--	--	64.7	159	0.405	2.72	27.3	2.1	207	49.2	439	64.8	92.5	661
4	Control, 80/20 jet-treated groundwood[a]/kraft	--	--	--	63.6	119	0.533	4.80	43.5	2.0	346	51.9	71	53.4	91.5	509
5	Control, 100% untreated groundwood	150	630	22.6	62.2	160	0.389	2.24	12.5	1.3	194	19.3	558	63.6	92.9	698
6	Groundwood jet cooked 6 sec at 230°F with 6% NaOH	90	590	23.0	63.4	124	0.511	4.84	35.7	1.7	317	21.5	56	50.8	93.0	531
7	Groundwood jet cooked 6 sec at 230°F with 6% NaOH & 3% Na_2SO_3	105	610	23.8	62.3	124	0.502	5.43	42.2	1.8	366	22.8	41	54.7	91.6	482
8	Groundwood jet cooked 6 sec at 230°F with 6% NaOH & 1% H_2O_2	100	590	21.5	61.4	126	0.487	4.36	31.5	1.8	277	21.2	86	60.7	90.1	576
9	Groundwood jet cooked 6 sec at 230°F with 6% NaOH & 0.5% $NaBH_4$, pH 7[b]	90	590	23.1	63.2	125	0.506	5.04	37.0	1.7	312	22.5	50	58.2	90.3	498
10	Groundwood jet cooked 6 sec at 230°F with 6% NaOH & 0.5% $NaBH_4$, pH 5[c]	100	585	24.6	63.2	123	0.514	5.29	39.6	1.8	324	21.5	39	56.1	91.2	495
11	Control, bleached groundwood 2% H_2O_2	150	--	--	63.9	175	0.365	2.12	16.9	1.6	181	17.8	504	73.0	90.7	716
12	Bleached groundwood (jet cooked 6 sec at 230°F with 6% NaOH) — 2% H_2O_2	90	--	--	66.0	121	0.544	4.79	43.0	1.9	352	19.7	33	70.0	83.4	461

[a]Jet cooked 6 sec at 230°F with 6% NaOH.
[b]pH adjusted to 7 with SO_2 after jet cooking.
[c]pH adjusted to 5 with SO_2 after jet cooking.



Legend:

1. Hopper
2. Moyno Pump
3. High-Pressure Steam Inlet
4. Jet Reaction Chamber
5. Pressure Indicators
6. Temperature Indicator
7. Throttling Valve
8. Separator

Fig. 1. Schematic diagram of steam jet cooker

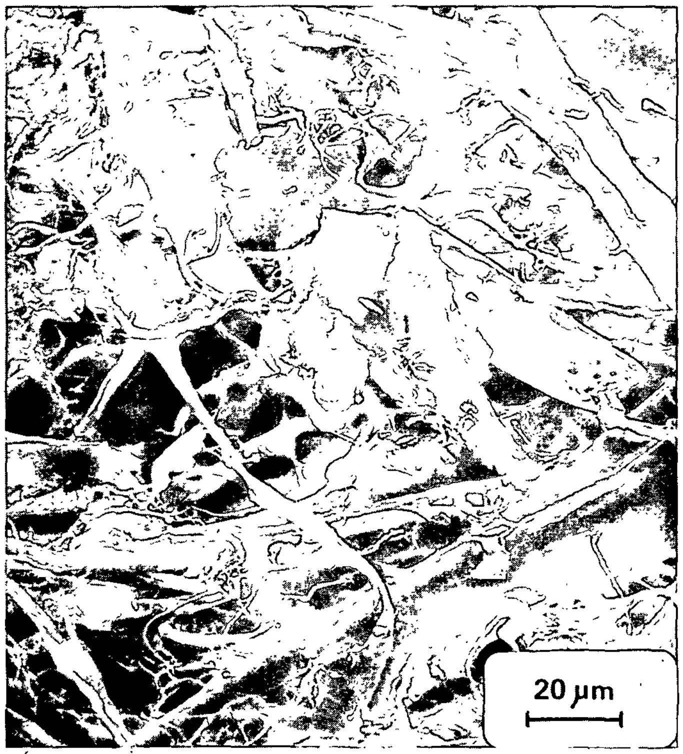


Fig. 2. Paper from untreated aspen groundwood, 600X

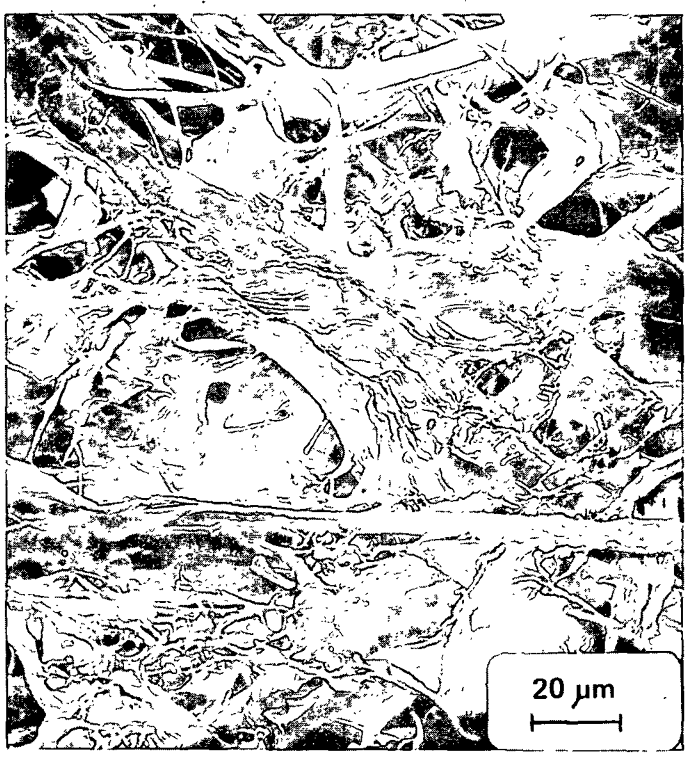


Fig. 3. Paper from jet/alkali-treated aspen groundwood, 600X

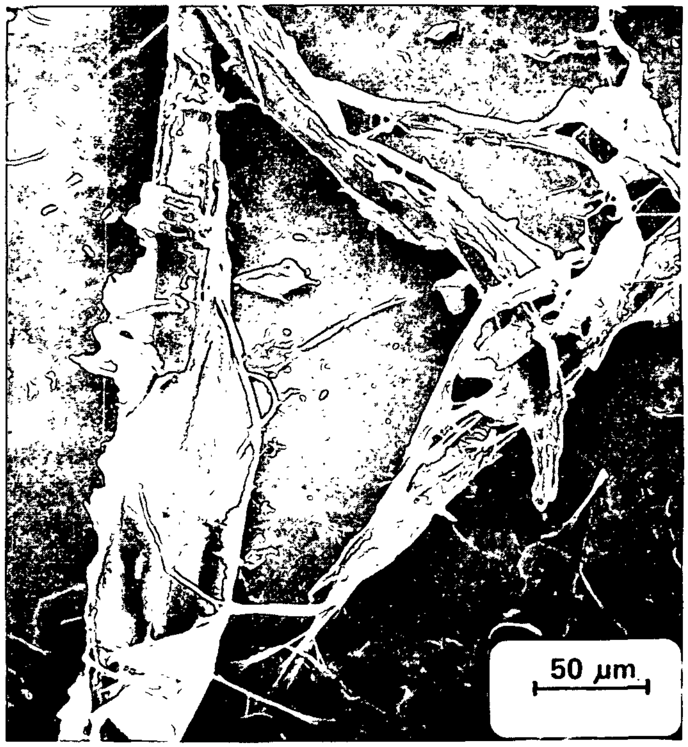


Fig. 4. Jet/alkali-treated aspen groundwood, 300X